Compression of picosecond optical pulses in tapered hollow-core photonic bandgap fiber

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Abstract: We demonstrate nonlinear compression of 2.5ps and 1.2ps laser pulses at 800nm wavelength using a 35m tapered hollow-core photonic bandgap fiber with continuously-decreasing dispersion.

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1. Introduction

In recent years, hollow-core photonic bandgap fibers (HC-PBGFs) [1] have emerged as highly attractive host media for a vast range of nonlinear optical phenomena. One such effect of great interest is the generation and guidance of optical solitons [2] which arise at high powers in HC-PBGFs when the greatly reduced Kerr nonlinearity balances the effect of anomalous dispersion. The development of tapered HC-PBGFs means that it is now possible to continuously decrease the chromatic dispersion of a HC-PBGF along its length. Both tapered and untapered HC-PBGFs have been used for the compression of femtosecond solitons [3,4]. In tapered HC-PBGFs [3] we recently demonstrated the compression of 195fs pulses to 90fs after propagation through an 8m tapered fiber using mainly the adiabatic soliton compression effect. In this paper, we build on our previous work to demonstrate greater compression of 2.5ps and 1.2ps input pulses using non-adiabatic effects over 35m of fiber, and with output pulse energies of 13-19nJ.

2. Experimental results

The tapered HC-PBGF which guides light at 800nm was fabricated by varying the capstan speed during the fiber drawing process, while keeping the preform feed rate constant. The fiber cross-section consisted of a 7-cell hollow-core surrounded by rings of air holes as shown in the scanning electron micrograph in figure 1(a). Unintentional birefringence introduced during the fabrication process led to a slightly noncircular core and a polarization dependence of the fiber dispersion. The measured group-velocity dispersion curves for the taper input and output are shown in figure 1 (a) for the two orthogonal linear polarization states which experience different refractive indices labeled ‘index 1’ and ‘index 2’. The long dimension of the core was approximately 8.3µm and tapered up to 9.2µm over a distance of 35m. The minimum attenuation in a uniform fiber from the same draw was around 150dB/km, but can be expected to be somewhat higher in the taper.

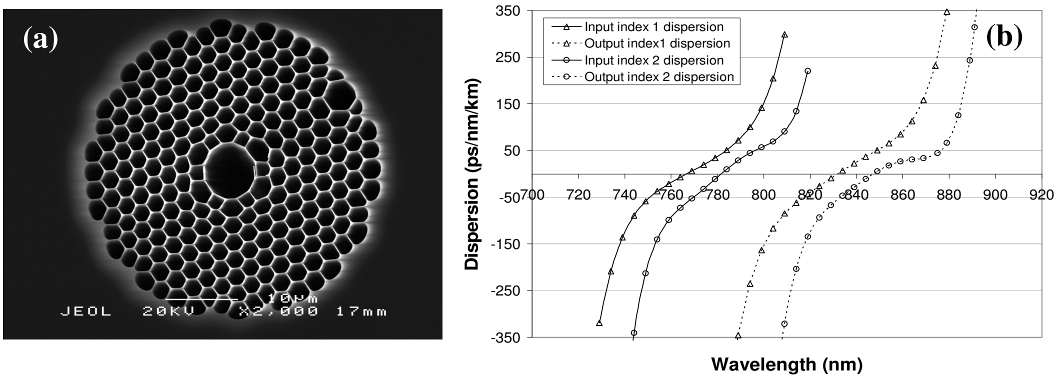

Fig.1. (a) Scanning electron micrograph image of the fiber cross-section; (b) Measured group dispersion profiles for the two fundamental polarization modes.

A mode-locked Titanium-Sapphire oscillator combined with a regenerative amplifier was used for our experiments, generating output pulses with energies of up to 4µJ, a central wavelength of 802.5nm and a repetition rate of 250kHz. The pulses were near transform limited with a duration of 160fs and a bandwidth of around 8nm. The pulses were temporally lengthened by means of a grating-pair-based femtosecond pulse shaper as described in [5], allowing pulses up to around 2.5ps with 0.65nm bandwidths to be formed by placing an adjustable slit in the Fourier plane.

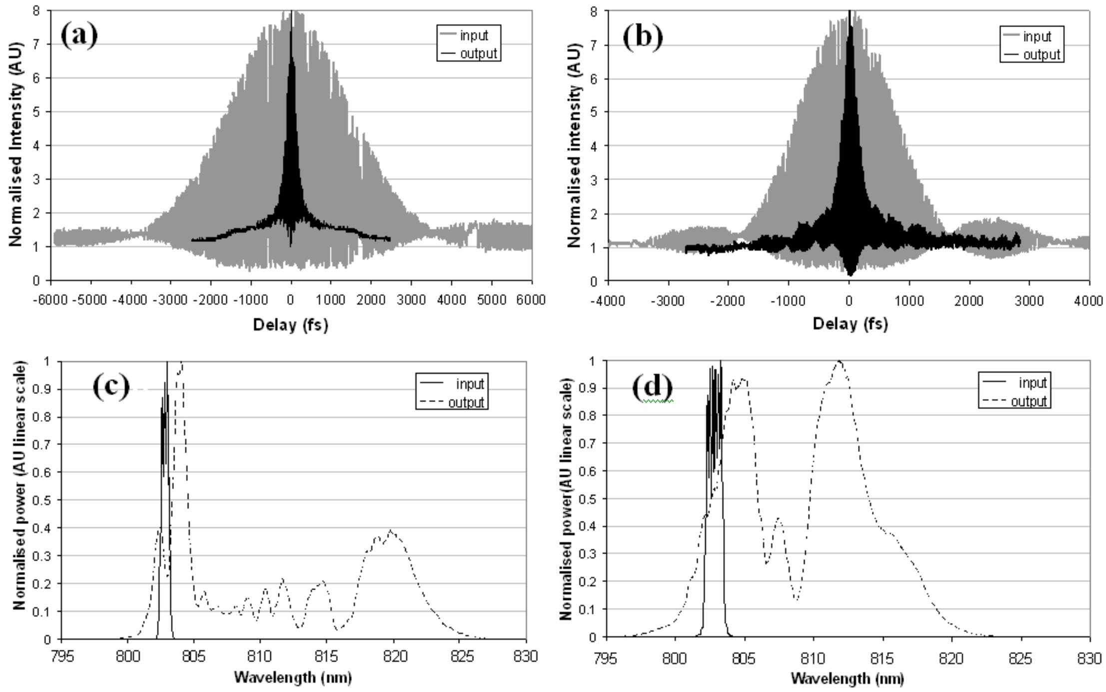

Fig. 2. (a) Autocorrelation traces for the 2.5ps input (grey curve) and the 13.0nJ fiber output (black curve); (b) Autocorrelation traces for the 1.2ps input and 19.4nJ fiber output (black curve); (c) Input (solid line) and output (dashed line) spectra for the 2.5ps input case; (d) Input (solid line) and output (dashed line) for the 1.2ps case.

The grey curves of figures 2(a) and (b) are the autocorrelation traces for the 2.5ps and 1.2ps pulses measured using an autocorrelator based on 2-photon absorption in an AlGaAs LED. The solid curves of fig. 2 (c) and (d) are the spectra of the pulses after propagation through the pulse shaper. The pulses were then coupled into the smaller-diameter end of the taper via a half-wave plate which was used to control the input polarization. Coupling efficiency was around 65%. The input polarization was rotated until optimum compression was achieved. Figure 2(a) shows compression of the input 2.5ps pulse with 13nJ at the fiber output, with the corresponding spectrum in figure 2(c). Figure 2(b) shows the compression to for the 1.2ps input case with an energy of 19.4nJ with the spectrum shown in figure 2(d). In each case the autocorrelation trace shows that the output pulse is chirped, due at least in part to the short length of normal-dispersion fiber at the output end of the taper (figure 1(b)). There is also an obvious self-frequency shift to longer wavelengths caused by intrapulse Raman scattering. The temporal soliton at the fiber output is identified with the spectral peaks around 820 nm and 813 nm in fig 2(c) and (d) respectively. The input soliton number is estimated to be around n=2 for the 1.2ps input pulse length. The compression factor is impressive, but overall performance is limited by the intrinsic inefficiency of the non-adiabatic conversion process.

Further work is in progress to better engineer the dispersion profile of HC-PBGF tapers in order to generate higher-quality compressed pulses. Our preliminary results presented here demonstrate impressive compression factors, and delivery of multi-nanoJoule femtosecond pulses in the 800nm wavelength range over 35m of any form of optical fiber represents a significant achievement.

References

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